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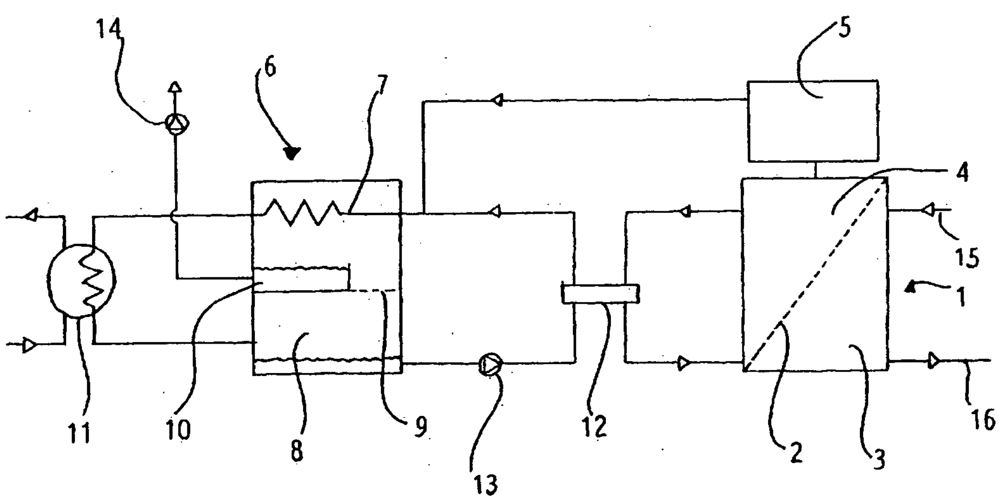
(54) Title: METHOD AND DEVICE FOR PRODUCTION OF DISTILLED FLUID AND EXERGY



(57) Abstract: Method for production of distilled liquid and exergy, comprising both osmosis and distillation. A liquid to be distilled is directed into a first side (3) of a membrane (2) in a membrane housing (1). The membrane (2) is only selective to molecules of a desired product of the liquid to be distilled. A second side (4) of the membrane (2) contains a liquid with high concentration of molecules not able to pass the membrane, in such a way that osmosis will occur. Parts of the highly concentrated liquids is directed via a generator (5), to a distillation apparatus (6), wherein the one of the distillation residue and the distillate containing the product, is removed as product, and the other is directed back to the second side (4) of the membrane (2). Device for production of distilled water and electrical energy, according to the method.

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Method and device for production of distilled fluid and exergy

The present invention relates to a method and a device for production of distilled liquid and exergy, according to the preamble of patent claim 1 and 9.

Background

There are many known methods for production of distilled water from sea water, brackish water, grey water and the like. The most familiar methods are reverse osmosis and distillation, but these kind of processes need considerable amounts of thermal and/or electrical energy. SE 458115 provides an example of a method for production of distilled water by evaporation.

The osmotic equilibrium pressure between freshwater and regular sea water containing 3 % salt, is 20 bar, and it is intended to utilize this for production of energy. In practice however, the pressure must be substantially reduced in order to achieve continuous flow across the membranes. This results in a huge need for fresh water and large membrane areas. An attempt to use this osmotic pressure is given in SE 403820.

The osmotic equilibrium pressure between saturated salt water (23 % salt) and fresh water, is 500 bar. In the same way as described above, efforts have be made to utilize this for production of electricity, among others at a pilot plant near Dødehavet. However, the consumption of fresh water was also very large also in this plant.

Object

The main object of the present invention is to provide a method and a device for production of distilled liquid and exergy. It is further an object that the method should utilize low temperature heat from solar collectors, geothermal sources, waste heat and the like.

The invention

The object is achieved with a method according to the characterizing part of patent claim 1, and a device according to the characterizing part of patent claim 9. Further advantageous features are stated in the various dependent claims.

The method for production of distilled liquid and exergy according to the present invention, comprises both osmosis across a membrane only selective to molecules of a desired product of the liquid which is to be distilled, and distillation. The liquid to be distilled, is directed to one side of a membrane in a membrane housing, while on the other side of the membrane, there is a

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liquid having high concentration of a type of molecules which are not able to cross the membrane, so that osmosis will occur as the molecules of the desired product flow across the membrane from the liquid which is to be distilled, and into the liquid having the high concentration.

The term "exergy" as used in this specification is intended to mean energy, or a part of energy, that may be transformed into another energy form, that is high-grade energy.

The liquid which is to be distilled, may be any type of liquid, but must be such that the molecules in a product of the liquid can pass a membrane, leaving the rest of the molecules behind. The liquid should be coarsely filtered at an earlier stage, in order to avoid those particles which may clog the membrane, being led into the membrane housing. Examples of liquids where the product is distilled water, is sea water, brackish water, grey water, rain water or ground water. In these cases there will only be the water molecules passing through the membrane.

The liquid on the other side of the membrane, from now on referred to as the highly concentrated liquid, could be any liquid having a boiling point substantially different from the boiling point of the product of the liquid which is to be distilled. The highly concentrated liquid may contain any type of molecules, in sufficient concentration to cause osmosis across the membrane. These molecules should of course not be able to pass the membrane. This leads to the edification of an overpressure, osmotic pressure, on the side of the membrane containing the highly concentrated liquid, compared to the other side. In case the product is distilled water being removed as distillate, the highly concentrated liquid may be completely or partly saturated salt or suger solution.

The membrane may be any type of membrane being selective towards some molecules, and withstanding the conditions prevailing during the osmosis in question, among others, the osmotic pressure arising during use. The membrane may be one single membrane, or preferably a part of a membrane battery, in known manner. In the case that the product is distilled water, the membrane must be selective towards water molecules.

Part of the highly concentrated liquid is led out of the membrane housing to a generator, utilizing the pressure of the liquid to generate exergy. This energy is used to operate the pumps of the system, and an eventual surplus is utilized in any known way, for instance transformed to electrical energy and supplied to the grid. In cases where the product is distilled water, and the membrane is of sufficient quality, considerable amounts of electrical energy may be exported from the system.

From the generator the highly concentrated liquid, now having a substantially lower pressure than in the membrane housing but still above atmospheric pressure, is directed to a distilling apparatus. The distilling apparatus may principally be any type of distilling apparatus, but it is preferred to use a heat exchanger distilling apparatus, comprising a first closed pipe system, and a distillation chamber, as the liquid in the first pipe system is heat exchanged with the liquid/ steam in the distillation chamber. The liquid from the generator is first lead through the first pipe system and chills the steam in the distillation chamber, before it enters the distillation chamber. The liquid may advantageously be heated or compressed after heat exchanging with the steam in the distillation chamber, before it enters the distillation chamber. A number of heat-exchange distillation apparatus of this kind are available on the market.

In cases where the product has a lower boiling point than the highly concentrated liquid, the distillation residue is directed back to the side of the membrane containing the highly concentrated liquid in the membrane housing, and the distillate is removed as product. In opposite cases, meaning when the highly concentrated liquid has a lower boiling point than the product, the distillate is directed back to the side of the membrane containing the highly concentrated liquid in the membrane housing, while the distillation residue is removed as product. In the following the invention will be described as if the product has the lower boiling point, and thus that the distillation residue is directed back to the side of the membrane containing the highly concentrated liquid, without this being interpreted as a limitation of the invention.

The pressure of the distillation residue will be considerable lower than the pressure on the side of the membrane, into which the residue is to be directed. This may be solved in many ways, for instance by means of pumps. In a particularly preferred embodiment of the present invention, part of the highly concentrated liquid is directed out of the membrane housing and pressure exchanged with the distillation residue from the distilling apparatus, before it is mixed with the liquid from the generator and directed into the distilling apparatus. The pressure exchanger can be any known type of pressure exchanger, but should raise the pressure of the distillation residue to a pressure being joinable with the pressure in the membrane housing, on the side containing the highly concentrated liquid.

In a particularly preferred embodiment of the present invention, the distillation is performed with negative pressure, meaning a pressure below atmospheric pressure. The distillate and the distillation residue are removed from the distilling apparatus via pumps driven by energy from the generator, with such strength that negative pressure is created in the distilling apparatus. This

lowers the boiling point of the liquid mixture, so that the distillation may be performed at lower temperatures. In cases where the distillate is distilled water, the distillation may be performed at temperatures below 100°C. Preferably there is still a pressure above atmospheric pressure in the highly concentrated liquid after the generator, and this, combined with the heating/ compression being performed before the liquid is directed into the distillation chamber, results in that the liquid is evaporating immediately in the distillation chamber.

In a particularly preferred embodiment of the invention, the highly concentrated liquid is heated before it is led into the distillation chamber, and the heat may advantageously be heat from a low-temperature plant, for instance from solar collector plants, geothermal sources or wasted heat. In this way solar energy can be used for distillation, and in cases where the generator produces more energy then needed by the pumps of the system, one may say that solar energy is being transformed to exergy, with simultaneous distillation of a liquid.

In some cases the aim may be production of exergy from low temperature heat, and not distillation of a liquid. In such cases, the distillate and the distillation residue may be directed back to the side of the membrane containing the corresponding liquid, and thus be circulated. Two different closed tube-systems will then arise, with a highly concentrated liquid in one of them. The system will be supplied with low temperature heat and produce exergy.

The present invention also comprises a device for production of distilled liquid and exergy. The device comprises a membrane housing, a generator and a distillation apparatus, connected in such a way that the liquid to be distilled is led into the membrane housing on a first side of the membrane, out of the housing from a second side of the membrane, and via the generator to the distillation apparatus, and that the product of the liquid can be removed as distillate from the distillation apparatus. At the same time a highly concentrated liquid, being defined above, circulates from the second side of the membrane, via the generator to the distillation apparatus, and the distillation residue is directed back to the same side of the membrane. In this way, both the highly concentrated liquid and the osmosis are maintained.

As mentioned above, there might be cases wherein the distillation residue is to be removed as product, and the distillate directed back to the side of the membrane containing the highly concentrated liquid. An example of such a case is when the liquid to be distilled is sea water, the membrane being selective to water molecules, and the highly concentrated liquid is methanol, having a boiling point of 64,5°C, at 1 bar.

The distillation apparatus of the device is preferably a heat exchanger distilling apparatus, being defined above, as the liquid to be distilled is first led through a closed pipe-system,

wherein it is heat exchanged with the contents of the distillation chamber, before it is directed into the distillation chamber. In order to secure that the distillation works at optimum, it is further an advantage that the liquid is heated before it is directed into the distillation chamber, and therefore the device comprises a heat exchanger before the inlet to the distillation chamber.

As said above, it is an advantage if the pressure of the distillation residue (distillate) is raised before it is directed back to the second side of the membrane in the membrane housing. Thus, the device also comprises a transfer tube from the side of the membrane containing the highly concentrated liquid, to the inlet of the distillation apparatus, and a pressure exchanger between the distillation apparatus and the membrane housing, wherein the liquid in the transfer tube is pressure exchanged with the distillation residue (distillate).

In cases where distilled liquid is not to be produced, just exergy, the device also comprises a recycle tube from the outlet of the distillate (or the outlet of the distillation residue) to the liquid inlet on the first side of the membrane.

Example

In the following the invention will be described with reference to the accompanied Figure, showing a particularly preferred embodiment of the invention. The device is designed for distillation of sea water, wherein the product is distilled water and removed as distillate from the distillation apparatus. The highly concentrated liquid is saturated brine.

The device shown in the Figure, comprises a membrane housing 1, having a membrane 2, and a first 3 and second 4 side. The device further comprises a generator 5 and a distillation apparatus 6, wherein the distillation residue is directed back to the second side 4 of the membrane housing 1. The distillation apparatus is of the heat exchanger distillation type, and comprises a first closed tube system 7, wherein the contents are heat exchanged with the contents of the distillation chamber 8, and a distillation chamber 8 with a drip-catcher 9 and a distillation bath 10, among others.

Between the outlet of the first tube system 7 of the distillation apparatus 6, and the inlet of the distillation chamber 8, there is a heat exchanger 11, wherein the liquid is heated with externally supplied heat. In the illustrated embodiment, the device is also provided with a tube from the second side 4 of the membrane 2 to the inlet of the first tube system 7 of the distillation apparatus 6, via a pressure exchanger 12. The outlet of the distillation residue is directed, through a pump 13 and the pressure exchanger 12, to the second side 4 of the membrane 2 in the membrane housing 1. The distillate is removed as distilled water from the distillate bath 10, via a

pump 14. In addition the device of course comprises an inlet 15 and an outlet 16 for the water which is to be distilled.

In use of the device according to Figure 1, water will flow out of the distillation bath 10 and correspond to the amount of water crossing the membrane 2 in the membrane housing 1, at any time. The amount of water crossing the membrane 2 will also correspond to the liquid flow difference in and out of the first side of the membrane 3, meaning the difference between the liquid flow through the inlet 15 and the outlet 16. In most cases the amount of water passing through the pressure exchanger 12 from the second side 4 of the membrane 2, to the inlet of the first tube system 7 of the distillation apparatus 6, corresponds to the amount of distillation residue, being removed via pump 13, to secure that the pressure exchanger 12 works satisfactory. The amount of liquid passing through the generator will thus also correspond to the amount of distillate being removed from the distillation bath, via pump 14. The amount of liquid being directed into the distilling apparatus will, of course, be the sum of the distillation residue and the distillate.

Estimation example

In a theoretical estimation example, sea water is led into the first side 3 of the membrane 2 of the membrane housing 1, at atmospheric pressure. On the second side 4 of the membrane, there is saturated brine (about 23 % salt). The osmotic pressure will in this case be about 400 bar. (Provided that a membrane standing a pressure difference of 400 bar is being used). Parts of the saturated brine is directed to a generator, reducing the pressure to about 20 bar. The generator will in this case produce a surplus of exergy, corresponding to about 10 kwh/m^3 brine. This surplus may be used in any known way, for instance transformed into electrical energy and supplied to the grid, or stored.

Parts of the saturated brine from the second side 4 of the membrane 2, having a pressure of 400 bar, is directed to a pressure exchanger where the pressure is reduced to 20 bar. The solution is then blended with the solution from the generator, and directed into the first tube system 7 of the distillation apparatus 6, wherein it is heat exchanged with water vapour in the distillation chamber 8. The solution is led further to a heat exchanger 11, where it is supplied with heat from a solar collector plant (not shown in the Figure), before it is led into the distillation chamber 8. The solution evaporates immediately in the distillation chamber 8, wherein the pumps 13 and 14, for the distillation residue and the distillate, respectively, keep the pressure below 1 bar.

Water of the brine evaporates, and rises towards the upper part of the distillation chamber 8. It passes the drip-catcher 9, and after cooling (meaning heat-exchanging with the first tube system 7 of the distillation apparatus 6) the condensate/distillate is collected in the distillation bath 10. The rest of the brine is collected at the bottom of the distillation chamber, and removed as distillation residue. The pump 13 increases the pressure in the distillation residue to about 20 bar. The distillation residue is directed, via the pressure exchanger 12 increasing the pressure to about 400 bar, back to the second side 4 of the membrane 2.

In the present invention the membranes used stand a pressure close to the theoretical osmotic pressure between the highly concentrated liquid and the liquid to be distilled (for instance 400 bar for seawater/brine). In cases where such membranes cannot be obtained, or they are very expensive, the pressure on the first side of the membrane may be increased, so that the pressure difference between the first and second side of the membrane becomes acceptable, in relation to the membrane used. This may be performed for instance by pressure exchanging the liquid in the inlet to the first side, with the liquid in the outlet from the first side and/or pumps.

With less pressure difference across the membrane, the flux, meaning the net transport across the membrane, will probably also be considerably better than with a large pressure difference.

In the above the invention is mainly described as a distillation device. If membranes and other equipment of sufficient quality can be obtained, the theoretically estimation example given above may be carried out, and the process will produce electrical energy in addition to distilled water.

It will be understood by persons skilled in the art, that the present invention is not only limited to what is mainly shown and described above. The invention also comprises combinations and sub-combinations of the described features, and modifications and variations of these being obvious to a person with knowledge of the known technique, and within the scope of the following claims.

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Claims:

1. Method for production of distilled liquid and exergy,
characterized in that the method comprises both osmosis and distillation, wherein

- a liquid to be distilled is directed to a first side (3) of a membrane (2) in a membrane housing (1), the membrane (2) is only selective to molecules in a desired product of the liquid to be distilled, a second side (4) of the membrane (2) contains a liquid with high concentration of molecules not being able to pass the membrane, so that osmosis will occur, and

- parts of the highly concentrated liquid is directed via a generator (5) to a distillation apparatus (6), wherein the one of the distillation residue and distillate containing the product, is removed as product, and the other is directed back to the second side (4) of the membrane (2).

2. Method according to claim 1, wherein the distillation apparatus (6) is a heat exchanger distillation apparatus comprising a first tube system (7) and a distillation chamber (8),
characterized in that the highly concentrated liquid is directed from the generator (5) into the first tube system (7) of the distillation apparatus (6), where it is heat exchanged with steam in the distillation chamber (8), before it is led into the distillation chamber (8).

3. Method according to claim 2,
characterized in that the highly concentrated liquid is further heated with external heat, preferably in a heat exchanger (11), after having passed the first tube system (7) in the distillation apparatus (6), before it is led into the distillation chamber.

4. Method according to claim 3,
characterized in that the external heat in the heat exchanger (11) is supplied from a low temperature plant, such as a solar collector plant, geothermal sources, waste heat and the like.

5. Method according to any one of claims 1-4,
characterized in that parts of the highly concentrated liquid are directed out of the membrane housing (1), and pressure exchanged in a pressure exchanger (12) with the one of the distillation residue or distillate being directed back to the second side (4) of the membrane (2) in the membrane housing (1), before it is blended with the liquid from the generator (5) and led into the distillation apparatus (6).

6. Method according to any one of claims 1-5, **characterized** in that the distillate and distillation residue are pumped out of the distillation apparatus (6) via pumps (13, 14), in such a way that the distillation is performed with negative pressure.

7. Method according to claim 6, **characterized** in that the exergy generated in the generator (5), is utilized to work the pumps (13, 14), and that a possible surplus is exported from the device.

8. Method according to any one of claims 1-7, **characterized** in that the product is directed back to the first side (3) of the membrane (2) in the membrane housing (1).

9. Device for production of distilled water and electrical energy according to any one of claims 1-8, **characterized** by comprising a membrane housing (1) with a membrane (2), and a first (3) and a second (4) side, a generator (5) and a distillation apparatus (6), wherein a liquid to be distilled is led into the membrane housing (1), and a product of the liquid being distilled is removed as distillate or distillation residue from the distillation apparatus (6).

10. Device according to claim 9, **characterized** in that the distillation apparatus (6) is a heat exchanger distillation apparatus, comprising at the least one first closed tube system (7) and a distillation chamber (8), wherein the liquid in the first closed tube system (7) is heat exchanged with the liquid/steam in the distillation chamber (8).

11. Device according to any one of claims 9-10, **characterized** by comprising a heat exchanger (11) supplied with external energy, wherein the liquid to be distilled is heated before it is led into the distillation chamber (8) of the distillation apparatus (6).

12. Device according to any one of claims 9-11, **characterized** by comprising a transfer tube from the second side (4) of the membrane (2), to the inlet of the destillation apparatus (6).

13. Device according to claim 12,
characterized by comprising a pressure exchanger (12) between the membrane housing (1) and the distillation apparatus (6), wherein the liquid in the transfer tube exchanges pressure with the one of the distillation residue and the distillate being led back to the membrane housing (1).

14. Device according to any one of claims 9-13,
characterized by comprising two pumps (13, 14) for removal of the distillation residue and distillate, respectively, from the distillation apparatus.

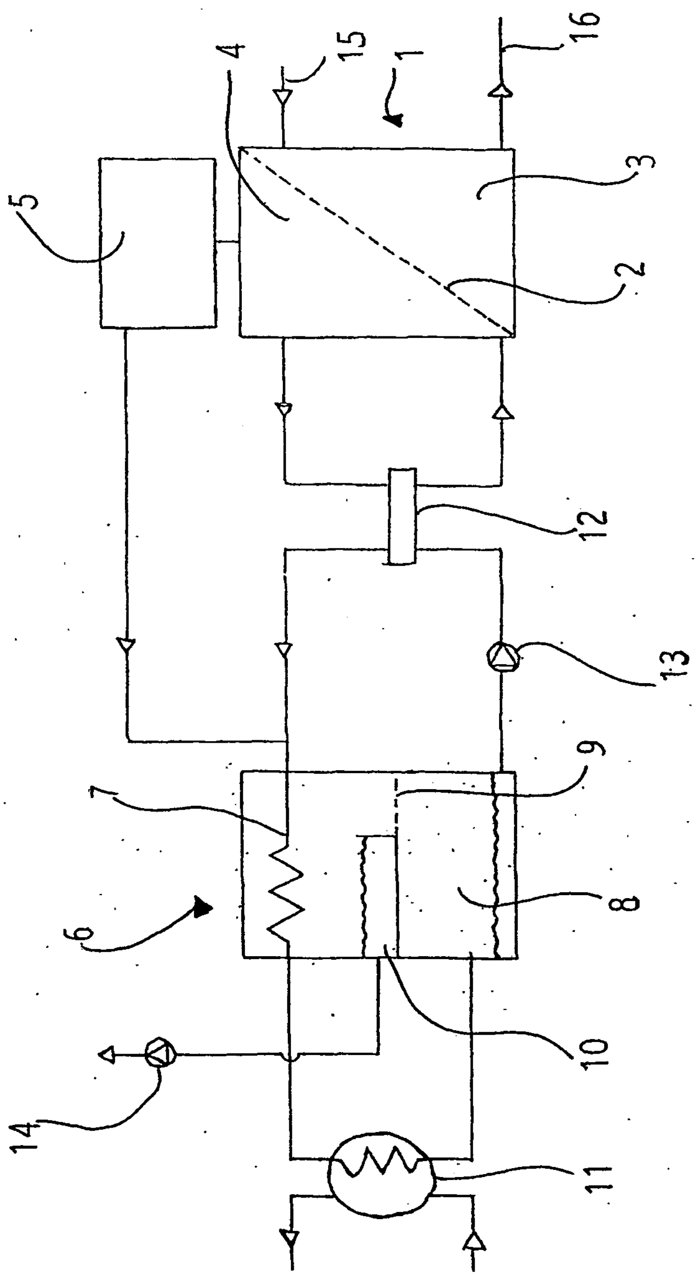

Fig.1

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 02/00054

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: C02F 1/04, C02F 1/44, F03G 7/04 // C02F 103:08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: C02F, F03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3906250 A (SIDNEY LOEB), 16 Sept 1975 (16.09.75), column 1, line 22 - line 34; column 2, line 25 - line 41; column 12, line 16 - line 48, column 13, line 28 - line 36; figure 11 --	1,9
A	US 4781837 A (MICHEL S.M. LEFEBVRE), 1 November 1988 (01.11.88), column 4, line 39 - column 5, line 8, figure 2 --	1-14
A	SE 403820 B (C G MUNTERS), 4 Sept 1978 (04.09.78), figure 1, claims 1-2 -- --------	1-14

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 April 2002	02-05-2002
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Bengt Christensson/MP Telephone No. +46 8 782 25 00

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